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REVIEW ON THE ADVANCEMENTS TO ADDITIVE MANUFACTURING-4D AND 5D PRINTING

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ABSTRACT

3D printing is established additive manufacturing technology in the Industry for quite a time. While the Additive Manufacturing industry is still discovering new applications, new materials, and new 3D printers, research is on for other technologies. 4D printing was started a year ago and recently 5D printing is being thought about and experimented. 4D printing has the ability to change the shape of 3D printed objects over time, which is the 4th dimension. 5D printing has the capability to print in 5 different axes thus printing the layers in any required layers and curves.

KEYWORDS: 4D Printing; 5D Printing & Additive Manufacturing

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Original Article

INTRODUCTION

4D printing is referred to as 3D printing transforming over time. Thus 4th dimension is added. So, the big break through about 4D printing over 3D printing is its ability to change shape over time. Itis the process through which a 3D printed object transforms itself into another structure over the influence of external energy input as temperature, light or other environmental stimuli. 4D printing relies on different kinds of materials and 3D models. The technology uses programmable materials that change their function when hot water, light or heat is added to the mix. The input to the 4D printing is a “smart material” that has thermo mechanical properties with other material properties and attributes that allow for shape change.

5D printing allows objects to be printed from 5 axes instead of from one point upwards. Objects in 5d printing are printed in various axes/angles unlike in 3D printing where it prints single direction. The printer head moves around from 5 different angles while printing as the plateau on which the object gets printed also moves. These movements make the printer head to print from different angles/direction to print the layers any required planes and curves, which is not achieved in 3D printing. This enables the printer head to follow the object’s shape and outline. Instead of following the straight path on a static plateau, the printer creates curved layers instead of flat layers. These curved layers make objects strong which have a complex design.

4D PRINTING

This technology is part of the project of MIT Self-assembly Lab. The purpose of this project is to combine technology and design to invent self-assembly and programmable material technologies aiming at reimagining construction, manufacturing, product assembly, and performance.

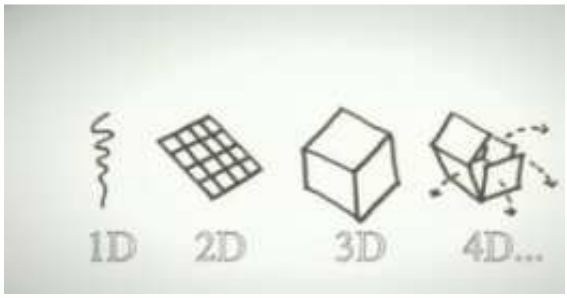

Figure 1: Fourth Dimension in 4d Printing

Below picture shows a 4D printed gripper grabs an object when the temperature is optimal.

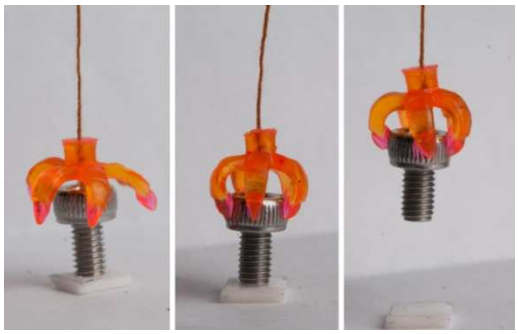

Figure 2: A 4D-Printed Gripper Grabs an Object when the Temperature is Optimal

The self-transformation ability of the material is a lead to a diversified application in various industries. Many key industries as Dassault Systemes S. A., Materialise NV, Massachusetts Institute of Technology, Hewlett-Packard, Inc., Stratasys, Ltd., 3D Systems Corporation are already developing 4D printing technology fortheir applications. Airbus SAS (France) is developing a technology to cool its jet engines using smart material that reacts to temperature and a wing that morphs according to aerodynamic conditions to decrease the air resistance. Briggs Automotive Company Ltd (U.K.) is developing a morphable wing for its supercar. The wing can adjust to external conditions such as rainstorm and automatically adjust itself to provide maximum downforce to the car. The U.S. Army Research Center is developing applications such as a soldiers uniform that can alter its own camouflage or provide more effective protection against poisonous gases or shrapnel upon contact, or changing coats on submarines to ensure their durability while traveling through different climate.

Resource and material management are today's subject of interest. 4D printing helps in the use of limited material for various purposes, as they can be changed into any form based on requirement. The higher cost of programming and printing technology are restraining the growth of this industry.

Global 4D Printing Market can be partitioned by (a) type of Material-Programmable Carbon fiber, Programmable textiles, Programmable wood grains and Programmable Biomaterial, (b) by type of industry -Healthcare, Aerospace & Defense, Automotive, Construction, Clothing and Others utilities, and (c) by geography -North America, Asia Pacific, Latin America, Europe, and Middle East.

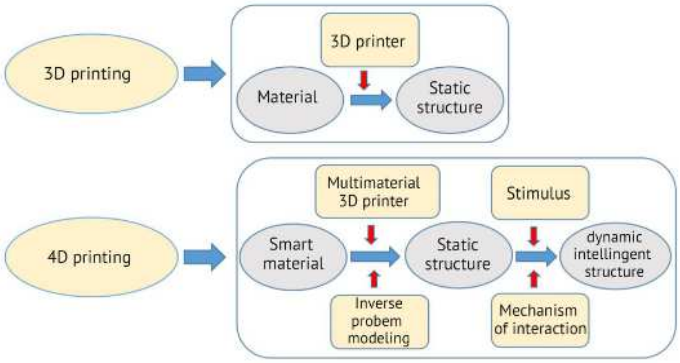

Figure 3: 3D vs 4D printing (Diagram by Jean-Claude André | Scientific Advisor at INSIS)

Benefits of 4D Printing

Through computational folding, objects larger than the printer can be printed as a single part. Since 4D printed object can change shape, can shrink and unfold, objects larger than the printer can be printed in the 3D printer in its compressed form and later with 4D technology it will form to its required shape and size. 4D printing has the vast potential to revolutionize the world of materials in the invention of smart materials. Materials like shown in below picture, where materials remember their shape and transform over time with stimulation of environmental conditions.

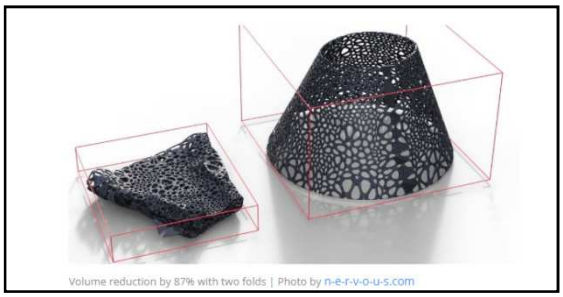

Figure 4: Volume Reduction by 87% with Two Folds | Photo by nervous.com

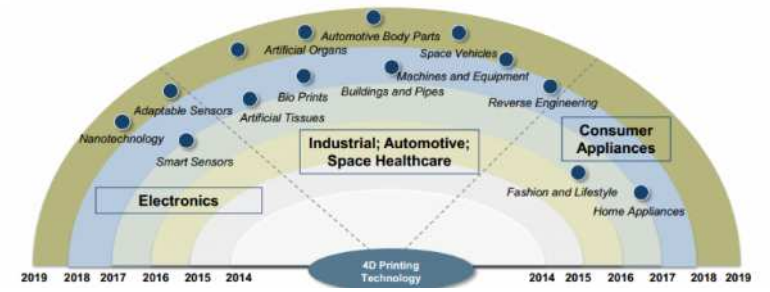

Figure 5

The chart represents applications that will be impacted by 4D printing technology in the next five years. (Courtesy of Frost and Sullivan analysis)

5D Printing

The 5D printing nature is a combination of additive and subtractive techniques. According to Mitsubishi Electric Research Laboratories (MERl), it requires quite an amount of analysis of the object being printed beforehand on how 5D printed parts will be used. The best use of 5D printing is for complex structures and designs that require a lot of strength.

Components which need to be strong in order to be functional in the industry and due to their requirement to comply with industry norms and safety requirements make 5D printing an important technological advancement.

As an example, a concave cap, an item that could not be 3D printed because it needs a lot of fillers and support and its design is very complex. Whereas 5D printing makes it easy print due to the capability to print curved layers. Below is the example of the 5D printed concave cap and it can be seen easily understand how it is not possible to print with 3D printing.

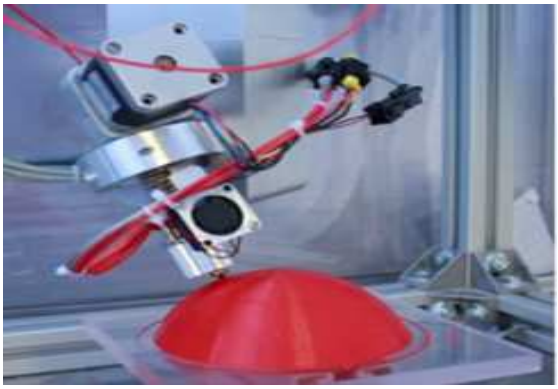

Figure 6: 5-axis 3D Printer

Halo 5D Printer

Ethereal machines, Bengaluru, India has made an innovation in additive manufacturing field for its creative and forward thinking for "Halo 5D printer". It has won 'Best of Innovation' prize in the field of 3D printing category at as Vegas Convention center of CES 2018. The machine can rotate and swivel the objects for making intricate designs for aesthetic or any utility purpose. This requires a kind of the suspension mechanism in 3D printers to print objects in 5 axes(3axis of movement and 2 rotational axes). With the developed 3D printing technology and CNC routers, Etherealteam combined both subtractive and additive techniques to come up with a variant on 5-axis machining. This printer can also cut soft metals and other materials for the creation of jewelery and car parts

Figure 7: Ethereal Halo 5D Printer

Table 1: Technical Specifications of Ethereal Halo (Courtesy Etherealmachines.Com)

Work area	Φ150 *150mm
Foot print	900*900mm
accuracy	60 microns
Load bearing capacity	8Kgs
Subtractive manufacturing materials	Choice of plethora of materials
Additive manufacturing materials	Supports more 3D materials
Extrusion mechanism	Geared direct drive mechanism
Spindle	800W DC motor ER-11 tool holder
Filament diameter	175mm
Extruder temperature	Upon 350^0C
Working speed	180mm/min
Power supply	25KW

3D vs 5D Printing

3D printing involves machining of flat layers to get the object profile and there are chances of weak points present in it. This is avoided by using the 5D printing technology. After printing objects with 5D printing and tested at MERL and was shown that they were 3 to 5 times stronger than the 3D printed objects. As a case study, in the MERL's Laboratory, the 3D printed and 5D printed pressure cups are pressurized which shows that the 3D printed cups could only handle 0.1 MPa and 5D printed cup could withstand 3.7 MPa before bursting. It was concluded that the 3D printed object has horizontal layers and which generated weak points. When there are forces pushing the layers in opposite direction to the direction in which these are printed, which can be down, up, through etc., layers would have parted from each other. These forces and enduring of these forces of the materials result in creating the stronger object. Another major advantage of this new technology is that it uses 25% less material compared to 3D printing.

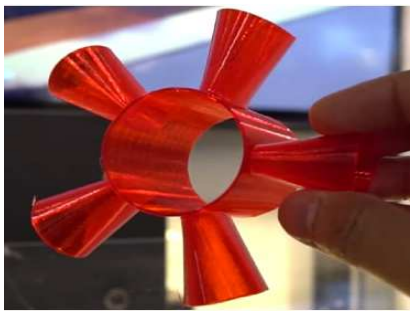

Figure 8: 5D Printed Concave Cap

Benefits of 5D Printing

Stronger Complex Objects can be made With Less Material. The machine also can cut soft metal and other material like nylon. Jewellery to automotive prototyping industry can be benefited.

CONCLUSIONS

Intense research is in progress in the area of Additive manufacturing and resulting in the new trends in 3D printing with the evolution of 4D and 5D printing. The main focus is towards smart materials, stronger materials and less material usage and hence less/no machining requirement.

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